DEPARTMENT OF COMMERCE
FREDERICK H. MUELLER, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

MONTHLY WEATHER REVIEW

JAMES E. CASKEY, JR., Editor

Volume 88
Number 3

MARCH 1960

Closed May 15, 1960
Issued June 15, 1960

CLOUD PICTURES FROM SATELLITE TIROS I*

S. FRITZ AND H. WEXLER

U.S. Weather Bureau, Washington, D.C.

[Manuscript received April 29, 1960; revised May 5, 1960]

ABSTRACT

Some of the more striking examples of cloud phenomena revealed by the first pictures that have come from the experimental weather satellite, TIROS I, are presented, and broad-scale patterns in the pictures are interpreted in terms of general features of the associated weather maps. These preliminary results show that a vast variety of scales appear in the cloud patterns associated with cyclonic vortices. Marked differences, as well as similarities, in cloud patterns associated with several types of cyclones are pointed out; the cyclones discussed include mature vortices in the Atlantic and Pacific Oceans, younger cyclones over and near the United States, and a typhoon in the South Pacific Ocean. The cloud cover over an extensive area is portrayed by means of preliminary mosaics of TIROS pictures and by a schematic cloud map made from the pictures.

1. INTRODUCTION

TIROS I, an experimental weather satellite (c.f. [1]) containing two television cameras was launched on April 1, 1960, by the National Aeronautics and Space Administration. The characteristics of the satellite, its cameras, and its orbit have been reported elsewhere [2]. By April 22, it had made about 300 orbits (apogee 461.3 stat. mi.; perigee 436.0 stat. mi.; inclination 48.4°; period 99.24 min.) and its cameras had taken about 6,000 pictures of various cloud formations. The purpose of this preliminary note is to present a few examples of these cloud pictures and to show their relation to observed weather patterns.

From among these first pictures that have come from TIROS some of the more striking examples have been selected. These have been put together in two ways. The first category portrays the large-scale vortex or cyclonic storm, several hundred miles in diameter. Pictures of seven individual vortices have been selected and their relationships to features of sea level weather maps are discussed. The location of the satellite in its orbit and the direction of view of its cameras at the time of each picture have not yet been determined precisely. However, approximate locations and directions that will serve the purpose of this preliminary report are indicated on the maps.

The second category is a composite array. One array consists of two mosaics of about 30 different prints and extends from a region about 800 miles west of Ireland to the Near East. Another array, in the form of a schematic representation of clouds, extends from the Pacific coast of the United States eastward over the Mediterranean to the Near East.

2. CLOUD PATTERNS OF CYCLONIC STORMS

The first category, figures 1–8, contains seven different examples of vortices observed by TIROS in both the Northern and Southern Hemispheres. With each picture, except figures 7 and 8, is shown the weather map associated with the vortex. The weather analyses were copied from the sea level maps of the National Weather Analysis Center, U.S. Weather Bureau, Suitland, Md.

Figure 1 shows the storm that was picked up in the

*This work has been supported by the National Aeronautics and Space Administration.

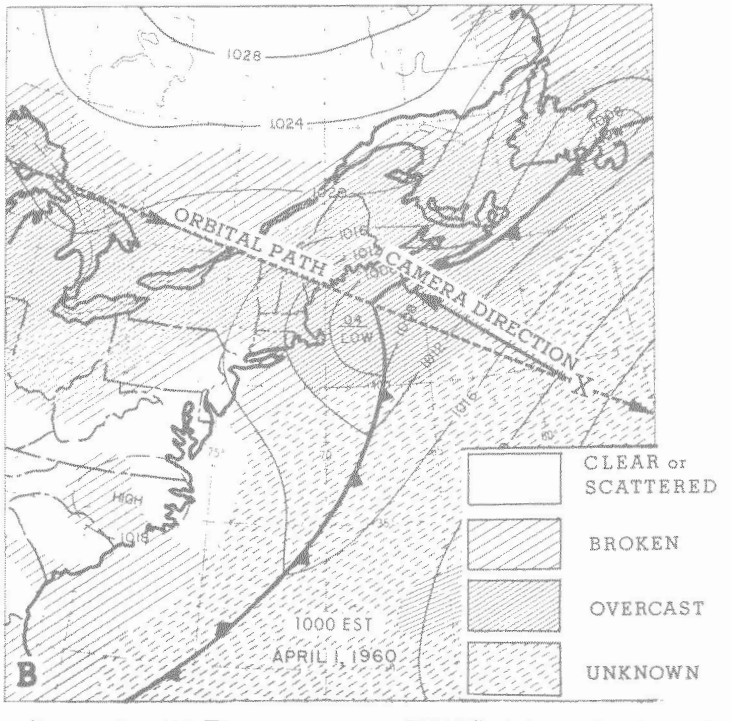
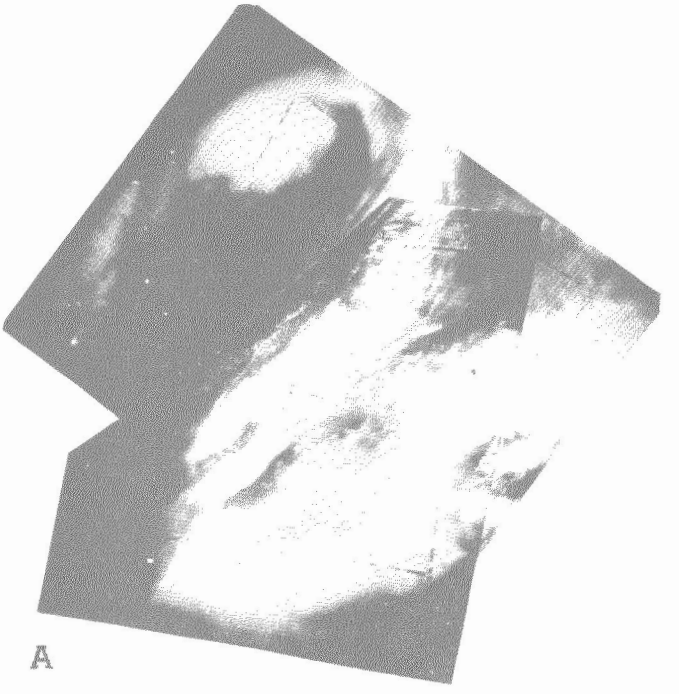


FIGURE 1.—(A) Three overlapping TIROS pictures showing extratropical cyclone centered about 120 miles east of Cape Cod, April 1, 1960. (B) Sea level weather map, 1000 EST, April 1, 1960. Point X denotes approximate location of satellite and the arrow indicates camera direction when pictures were taken.



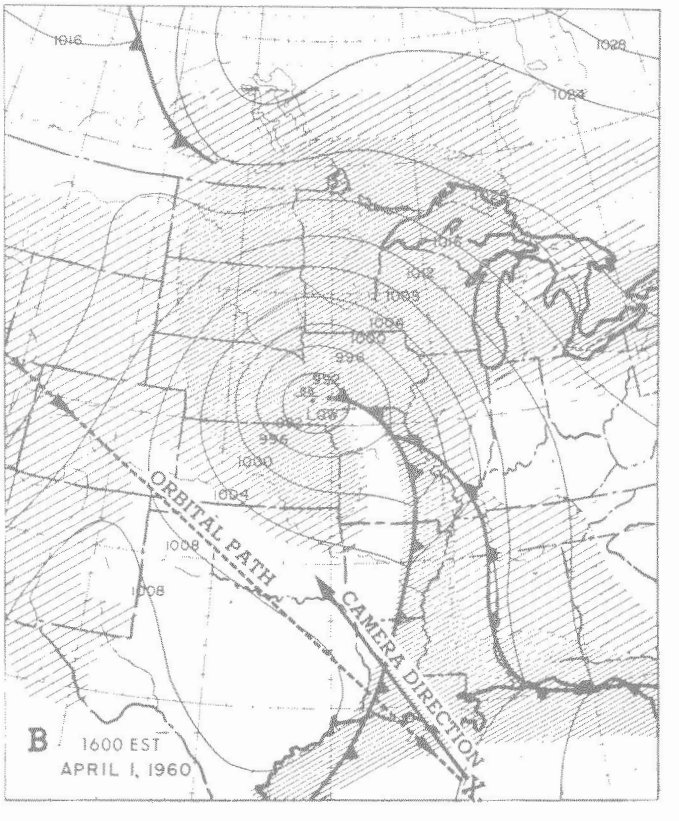


FIGURE 2.—(A) Two overlapping TIROS pictures showing extratropical cyclone centered over southeastern Nebraska, April 1, 1960. (B) Sea level weather map, 1600 EST, April 1, 1960. The key to the cloud cover analysis is given in figure 1B.

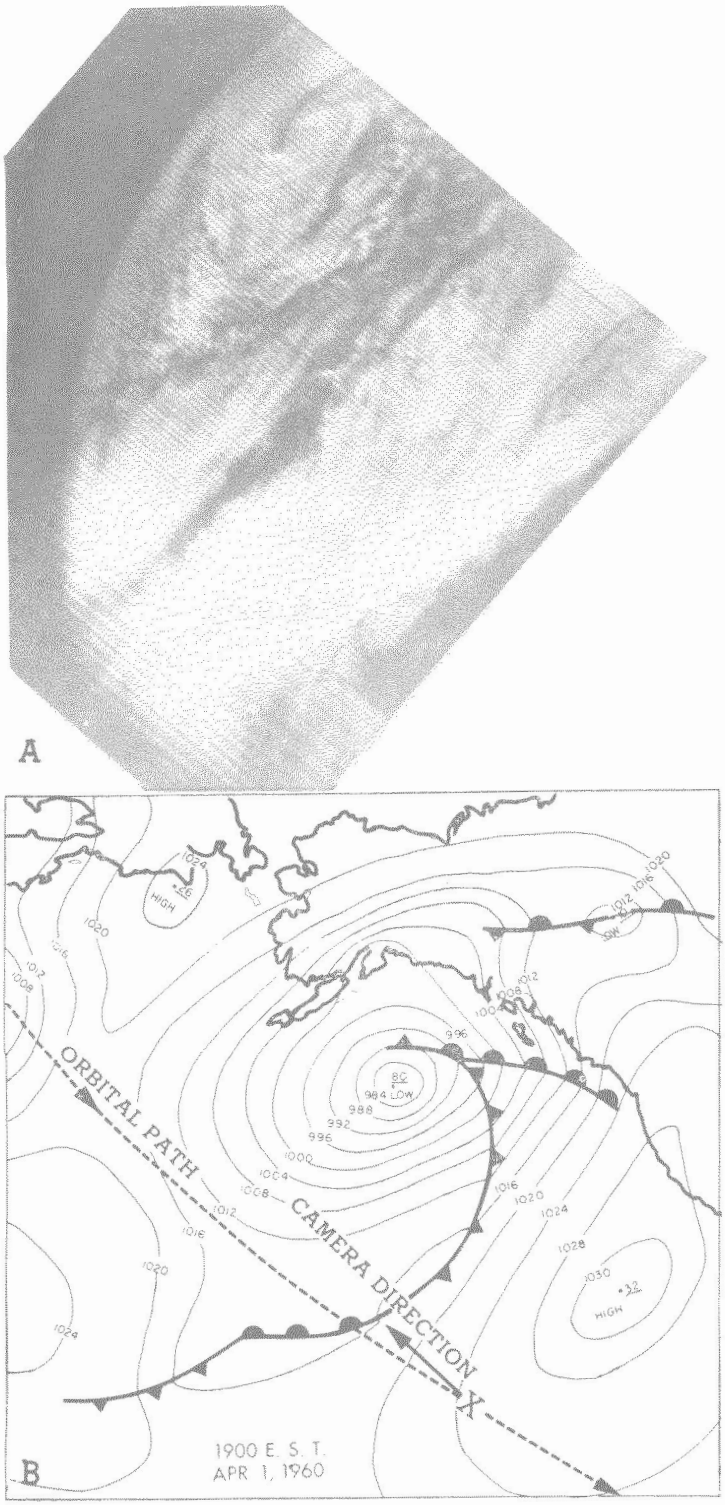


FIGURE 3.—(A) TIROS picture showing extratropical cyclone centered in the Gulf of Alaska about 500 miles southeast of Kodiak Island, April 1, 1960. (B) Sea level weather map, 1900 EST, April 1, 1960.

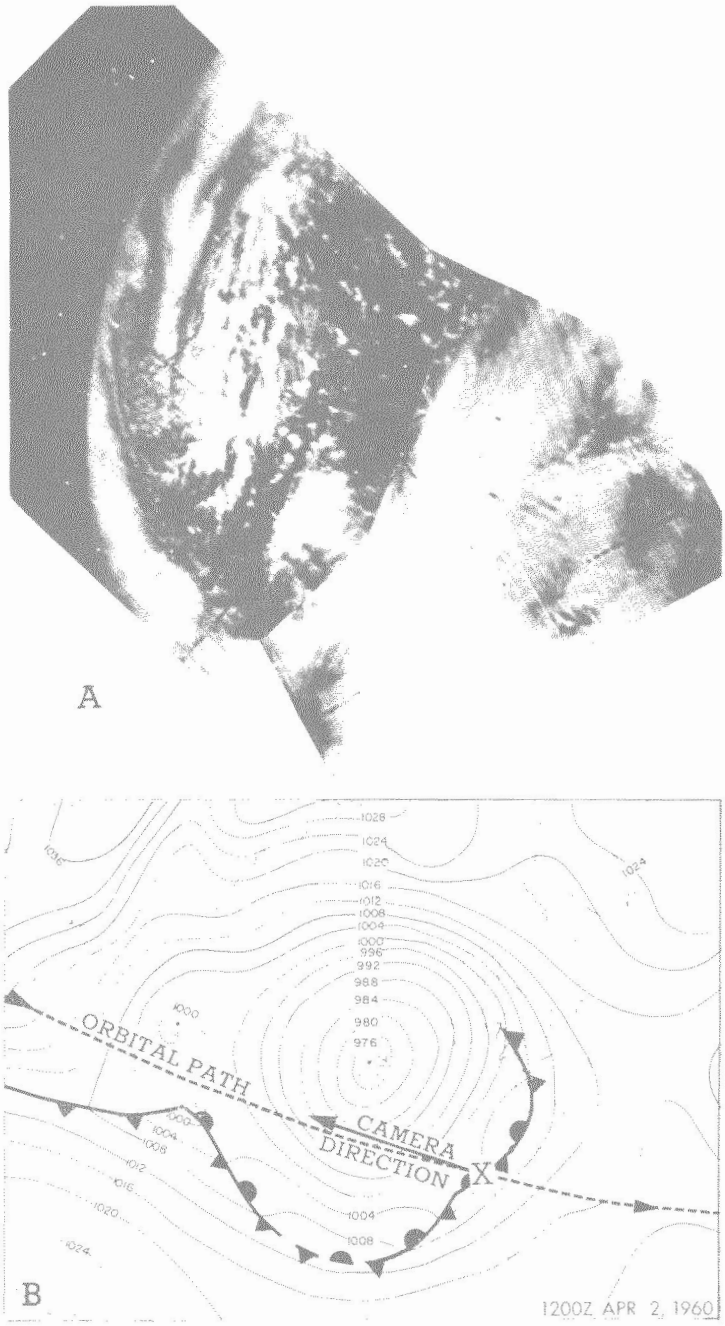
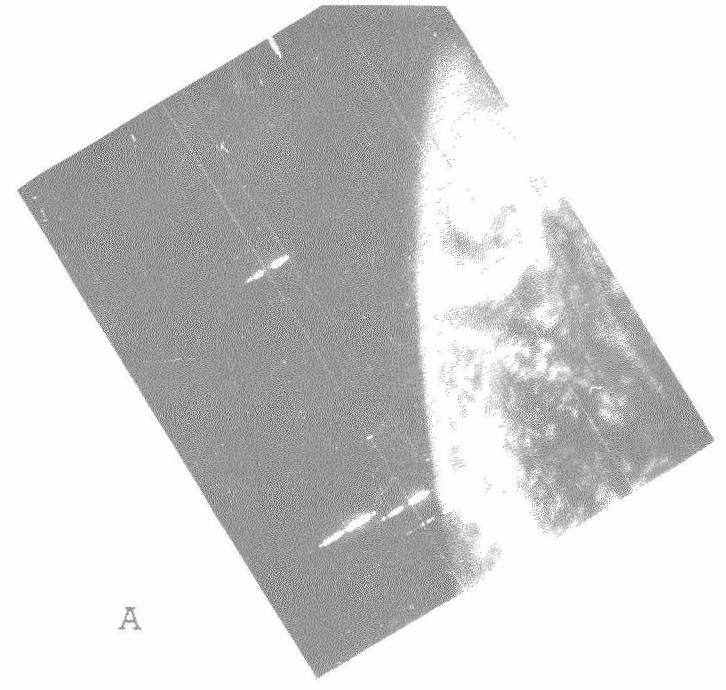


FIGURE 4.—(A) Two overlapping TIROS pictures showing extratropical cyclone centered about 400 miles west of Ireland, April 2, 1960. (B) Sea level weather map, 1200 GMT, April 2, 1960.



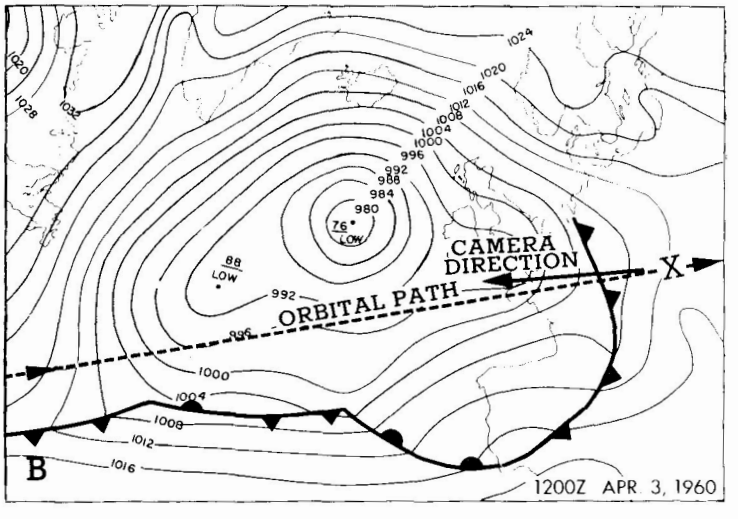
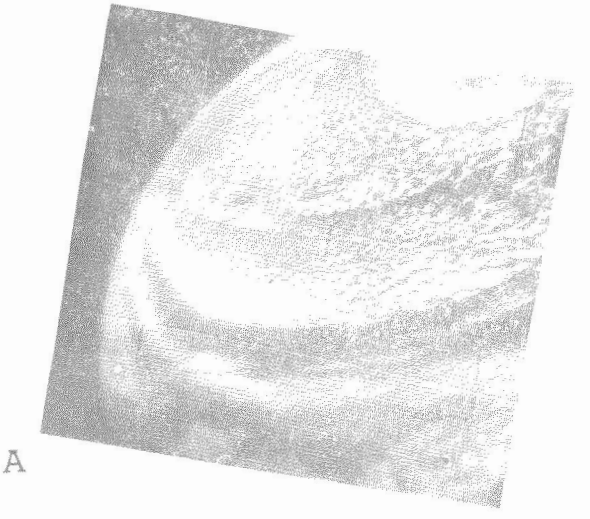


FIGURE 5.—(A) TIROS picture showing extratropical cyclone centered about 400 miles west of Ireland, April 3, 1960. This is the same storm pictured in figure 4A a day earlier. (B) Sea level weather map, 1200 GMT, April 3, 1960.



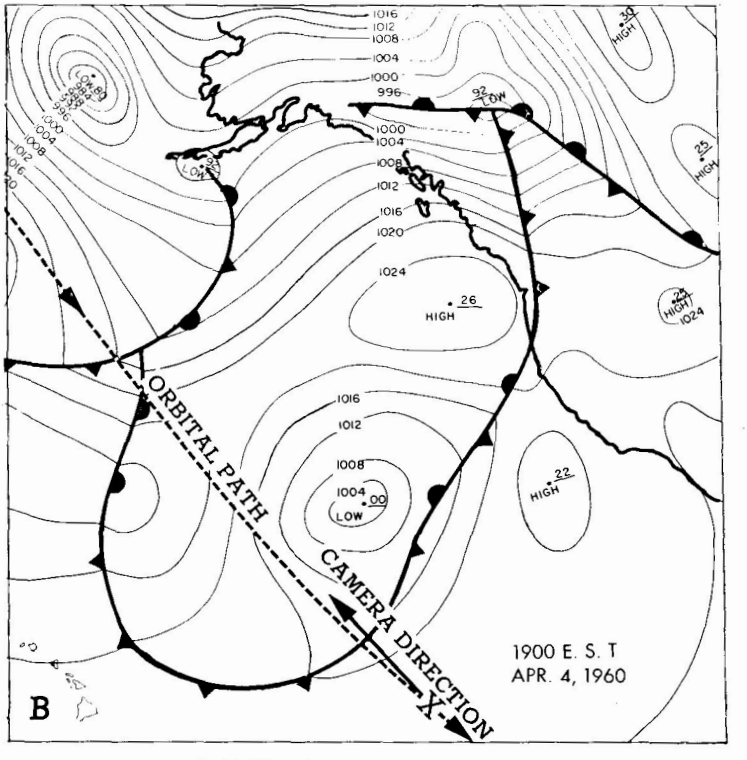


FIGURE 6.—(A) TIROS picture showing extratropical cyclone centered about 800 miles west of southern California, April 4, 1960. (B) Sea level weather map, 1900 EST, April 4, 1960.

early orbits of TIROS on the first day, April 1. The storm was centered 120 miles east of Cape Cod with continental air streaming off the east coast, and moist air over the ocean flowing northward, counterclockwise around the center, producing widespread clouds and precipitation as far north as the Gulf of St. Lawrence. Much of the Gulf of St. Lawrence and the St. Lawrence River was nearly cloudless as is indicated by the dark area near the top of the pictures.

Figure 2 shows a storm in midwestern United States that was also televised on April 1. This rather extensive storm was centered over southeastern Nebraska. Again, we see the clear, cold, dry air (represented by the dark area which is the ground underneath) moving in behind a cold

front. To the east of the front the moist air from the Gulf of Mexico is flowing into the storm center and producing rather widespread cloudiness, shown by the circular cloud near the top of the picture. Near the Gulf of Mexico, where very bright portions of the picture suggest that the clouds are very high, thunderstorms occurred.

Figure 3 shows a third vortex that was observed, also on April 1, in the Gulf of Alaska 500 miles southeast of Kodiak Island. The vortex circulation is clearly portrayed by the clouds which form a spiral array.

The associated weather map of the cyclone is based upon relatively few reports over an area which is larger than the United States; there is therefore opportunity for error because of lack of observations. The paucity of data is even more pronounced in the upper air. In these areas particularly, satellite observations similar to figure 3 will be useful in synoptic scale weather analysis as well as research.

Figure 4 shows a large, mature, occluded cyclone, about 1,000 miles in diameter, centered about 400 miles west of Ireland on April 2. The rather well-marked banded structure of the clouds of this ocean storm is quite different from the more uniform structure of clouds associated with continental and coastal storms whose cold fronts are followed by dry continental air (figs. 1 and 2). The storms over the oceans that TIROS has so far revealed seem to show more of a banded structure; the bands, ranging in width from a few miles to a few hundred miles, appear to spiral cyclonically around the storm center.

Figure 5, showing the same storm west of Ireland a day later, April 3, was photographed from a point farther to the southeast. From this view, in which the storm is near the horizon, there seems to be just one very large band winding around the center. Photogrammetric measurements may reveal the nature of the change in cloud pattern from April 2 to April 3.

Figures 6 and 7 show a cyclone located about 800 miles west of southern California on April 4 in an area where anticyclones are usually found. The storm has a cloud vortex about 1,000 miles in diameter. The cloud picture contains several scales of superimposed bands: first, a series of wide bands in which the clouds seem to start abruptly at a narrow clear zone, sometimes increasing in brightness with distance from the vortex center, only to end abruptly again in a clear zone; second, the individual bands composed of a series of smaller elements, and probably if the resolution were fine enough, there would be smaller elements within those. These are examples of the vast variety of scale of streakiness that characterizes the atmosphere.

The weather map (fig. 6B) associated with this cyclone is based on a few ship reports in the area between Hawaii and California, whereas the TIROS picture (fig. 7) reveals considerably detailed structure of the storm.

Figure 8 shows a vortex in the Southern Hemisphere, where cyclones rotate clockwise instead of counterclockwise. On April 10, this storm was located about 300 miles north of the northern tip of New Zealand. Note the dark, cloudless eye of the storm. The eye and spiral cloud bands of tropical cyclones, such as hurricanes and typhoons, have been studied by means of radar and aircraft photographs, but figure 8 shows the first single picture of a nearly complete typhoon structure as seen from high levels.

The existence of this tropical storm was known to meteorologists in the Southern Hemisphere for several days before TIROS televised it on April 10; after a message was received indicating that a storm was there, the satellite was then programmed to observe it. (TIROS can store pictures taken during only a 16-minute interval; therefore, whenever possible, it is programmed to take pictures of interesting meteorological areas on the daylight side of the earth.) This is one of several pictures taken about 0300 GMT, April 10.

The vortices that have been shown in this section are examples of the most striking phenomena that TIROS has revealed so far. It will now be necessary to study the hydrodynamics and thermodynamics which produce such cloud patterns, to acquire a greater understanding of atmospheric processes, which will then lead to a better interpretation of the cloud pictures.

3. CLOUD PATTERNS OVER EXTENDED AREAS

The second category of cloud information, shown in figures 9 and 10, is the cloud cover and patterns over an extensive area having dimensions far greater than those represented in the individual pictures shown in the preceding section. This different type of cloud information is obtained by overlapping a series of TIROS pictures to make a mosaic (fig. 9) and by deriving a schematic cloud map (fig. 10) from the pictures.

Figure 9 is a mosaic of about 30 pictures taken on orbits 14 and 15 as the satellite moved toward the southeast on April 2. The pictures start about 800 miles west of Ireland to the west of the vortex that was mentioned earlier (fig. 4). On orbit 14, a picture of the vortex was taken and 100 minutes later on orbit 15 another picture of the same storm was taken. The same cloud details can be recognized over the 100-minute interval. The mosaic gives a geographical coverage of cloud patterns beginning in the Atlantic Ocean. They include the vortex west of Ireland and show the extensive cloud area over western Europe, a massive cloud over the Swiss Alps, a general cloud area over Turkey, and a clear area in the Near East, Israel, Egypt, and North Africa.

Figure 10, based on pictures from orbits 28 and 32, on April 3, is a preliminary schematic representation of clouds over an area extending from the west coast of the United States into the Atlantic Ocean, and then from the mid-Atlantic and Europe to the Near East. Selected photographs, from which the schematic array was made, are displayed along the boundaries of the photographed area.

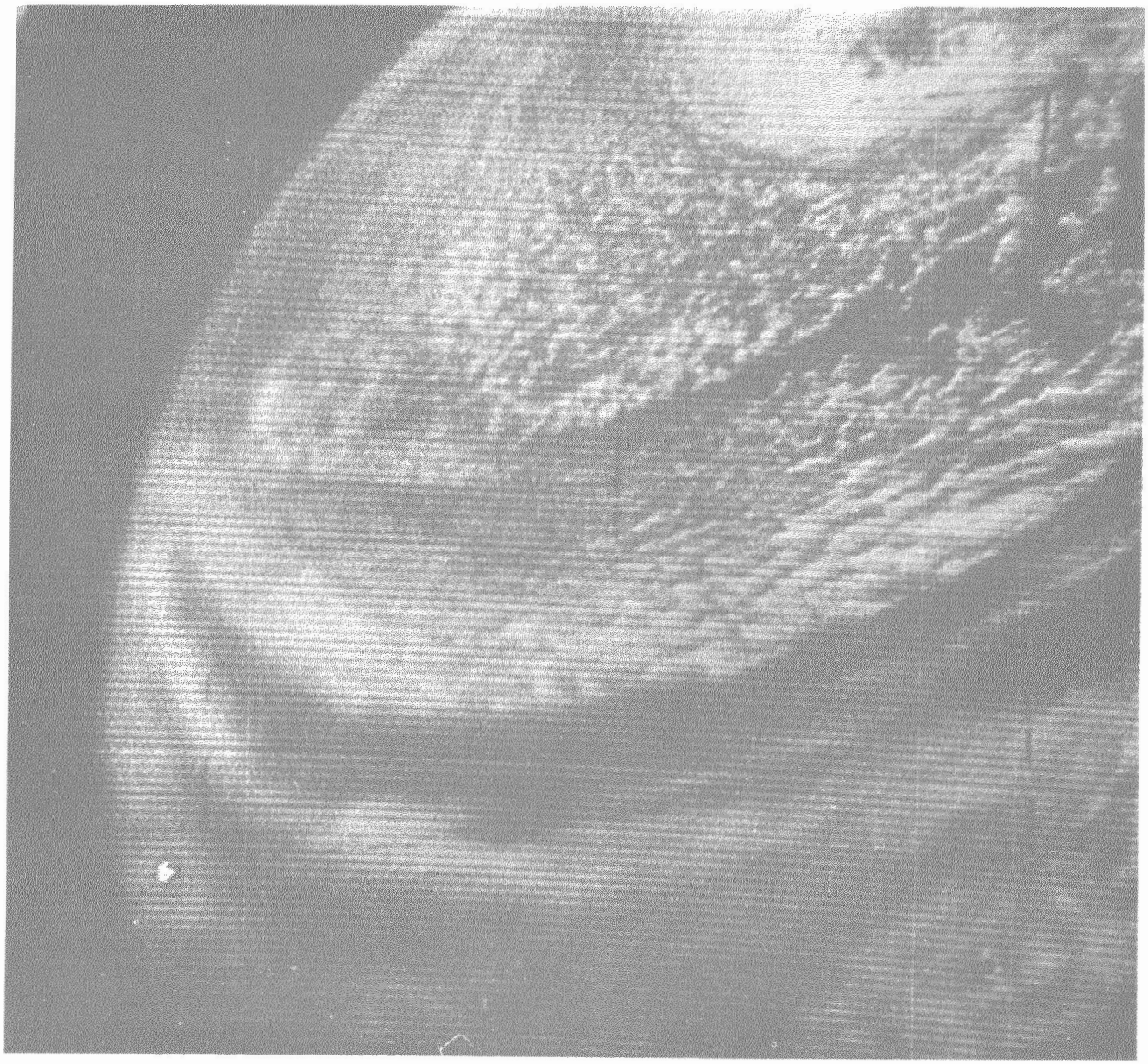


FIGURE 7.—Enlarged TIROS picture of the extratropical cyclone shown in figure 6. Notice the variety of scales shown by cloud patterns.

Some features of the mosaic in figure 9 on the previous day can be seen, as for example the vortex west of Ireland.

4. SUMMARY

TIROS has revealed a large degree of organization in the cloud systems over much of the earth's surface. The most striking patterns are the spiral cloud formations associated with large storms, some as much as 1,500 miles in diameter, observed in such places as the United States, North Atlantic Ocean, North and South Pacific Oceans, and the Indian Ocean (not shown here).

It is well known from radar observations that hurricanes are characterized by bands of clouds which spiral inward around a storm center. Although some suggestions have been made that extratropical cyclones also contain bands, over oceans, now as a direct result of TIROS, we see that the spiral banded cloud structure also exists around well-developed extratropical storms. Compare, for example, figures 7 and 8. In these storms the bands are separated by clear areas and range in width from several miles to a few hundred miles. Also the storm 400 miles west of Ireland (fig. 5), which is not a tropical storm, can be compared with the tropical storm north of New Zealand (fig. 8). In both cases, the cloud bands revealed the circular wind flow around the storm's center. But one of the sig-

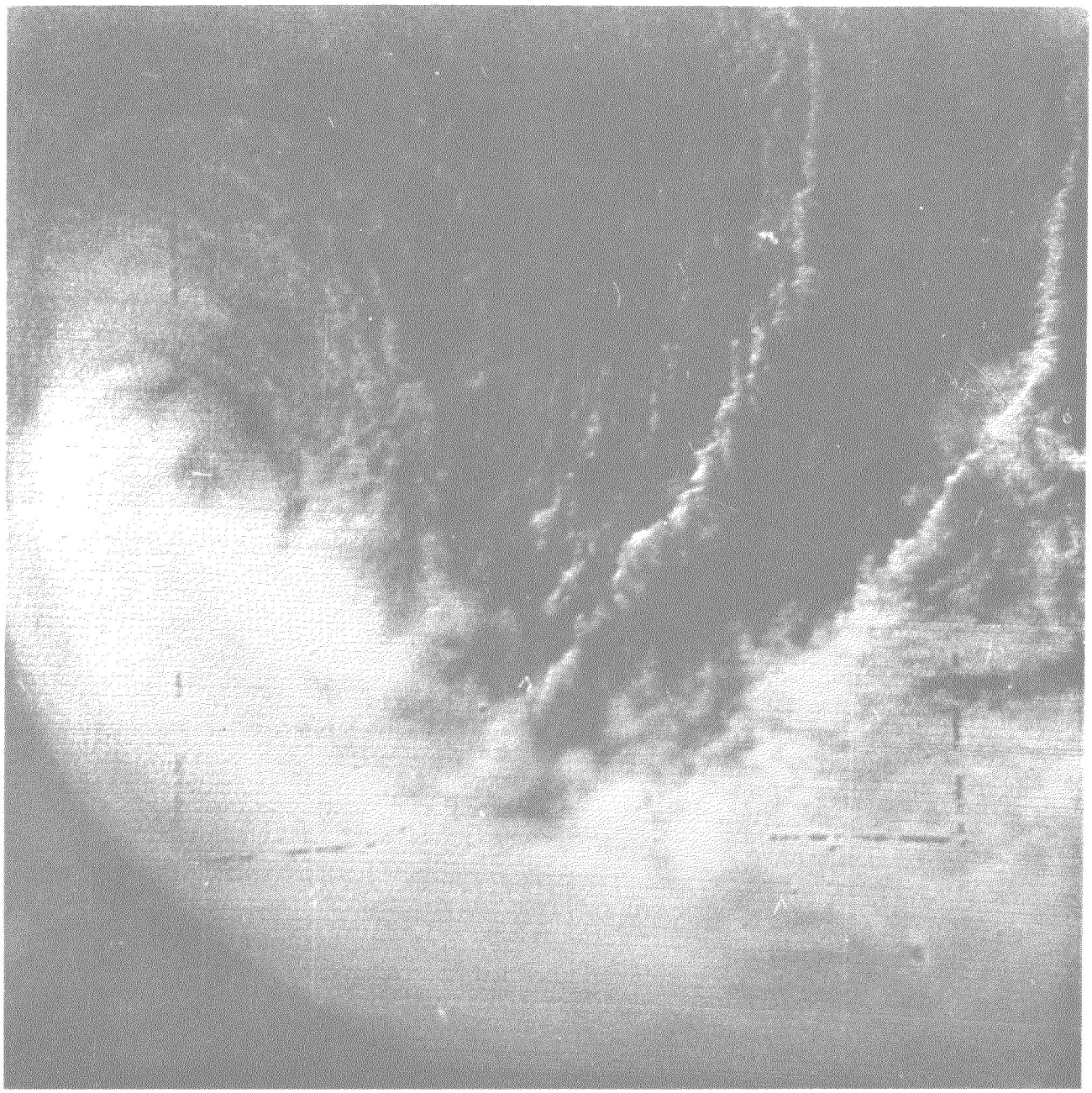


FIGURE 8.—TIROS picture of tropical cyclone centered north of New Zealand, April 10, 1960.

nificant results from TIROS is the clear indication that although storms have similarities, there may also be very marked differences. Study of the causes for these differences should reveal much about atmospheric processes and structures.

Thus far, storms observed over continents have not exhibited such fine banded structure as those over oceans. The continental storms have been associated with general cloud areas with the spaces between the bands either poorly defined or non-existent but the spiral nature of the storm was indicated more by the presence of a wedge of dry, cloudless air curving in toward the storm center behind a cold front, as shown by the Midwest storm of April 1 (fig. 2). A storm photographed on the east coast of the United States on the same day also showed this clearly (fig. 1). It had a similar cloud system without the marked banded structure. However, we do see again the cold cloudless air flowing in behind the cold front. Moreover, both of these storms contained frontal systems.

The photographs shown here are but a few of the more striking examples of cloud pictures revealed by TIROS. A systematic inspection of these cloud pictures is just

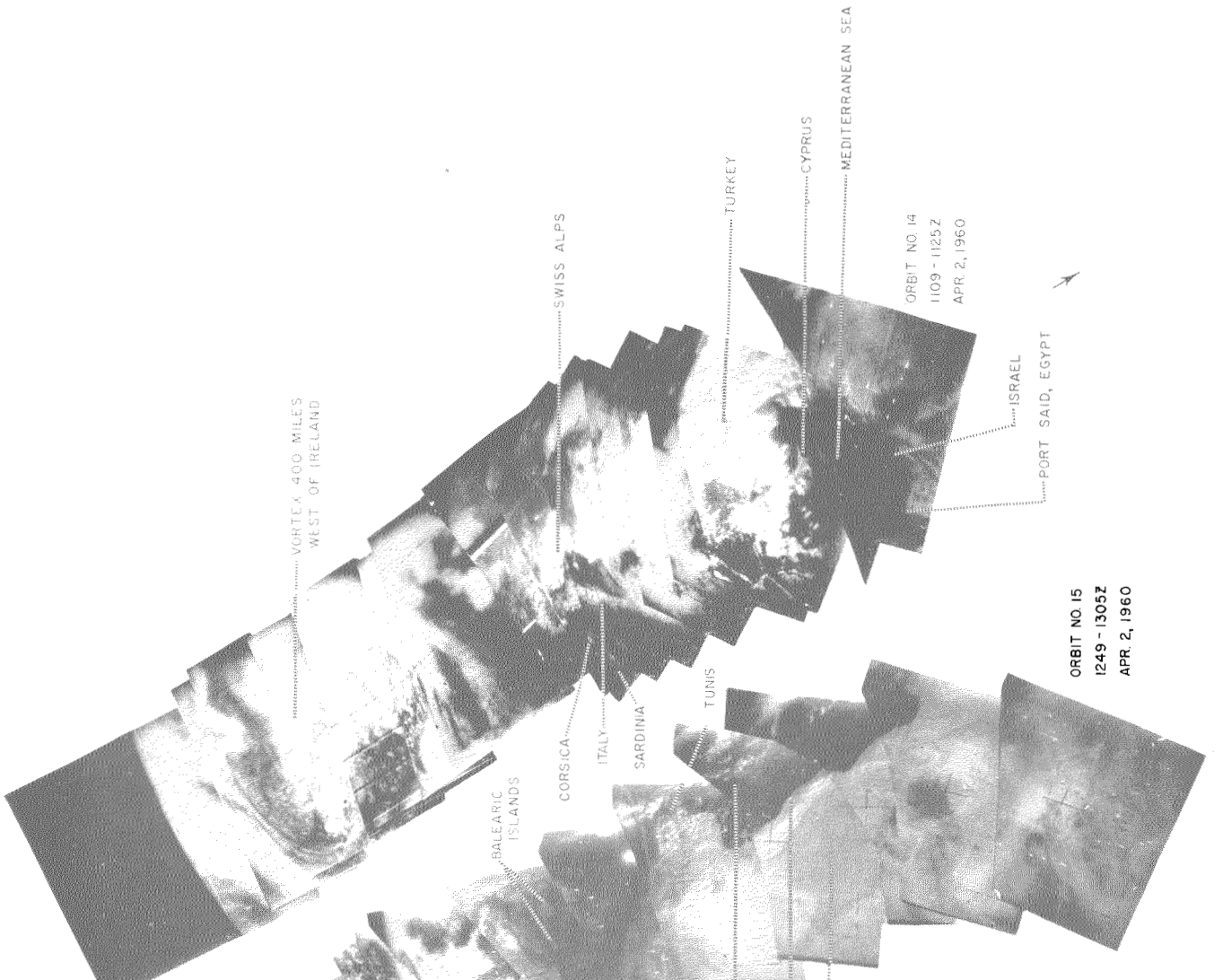


FIGURE 9.—Two preliminary mosaics obtained by overlapping a series of TIROS pictures on orbits 14 and 15, April 2, 1960.

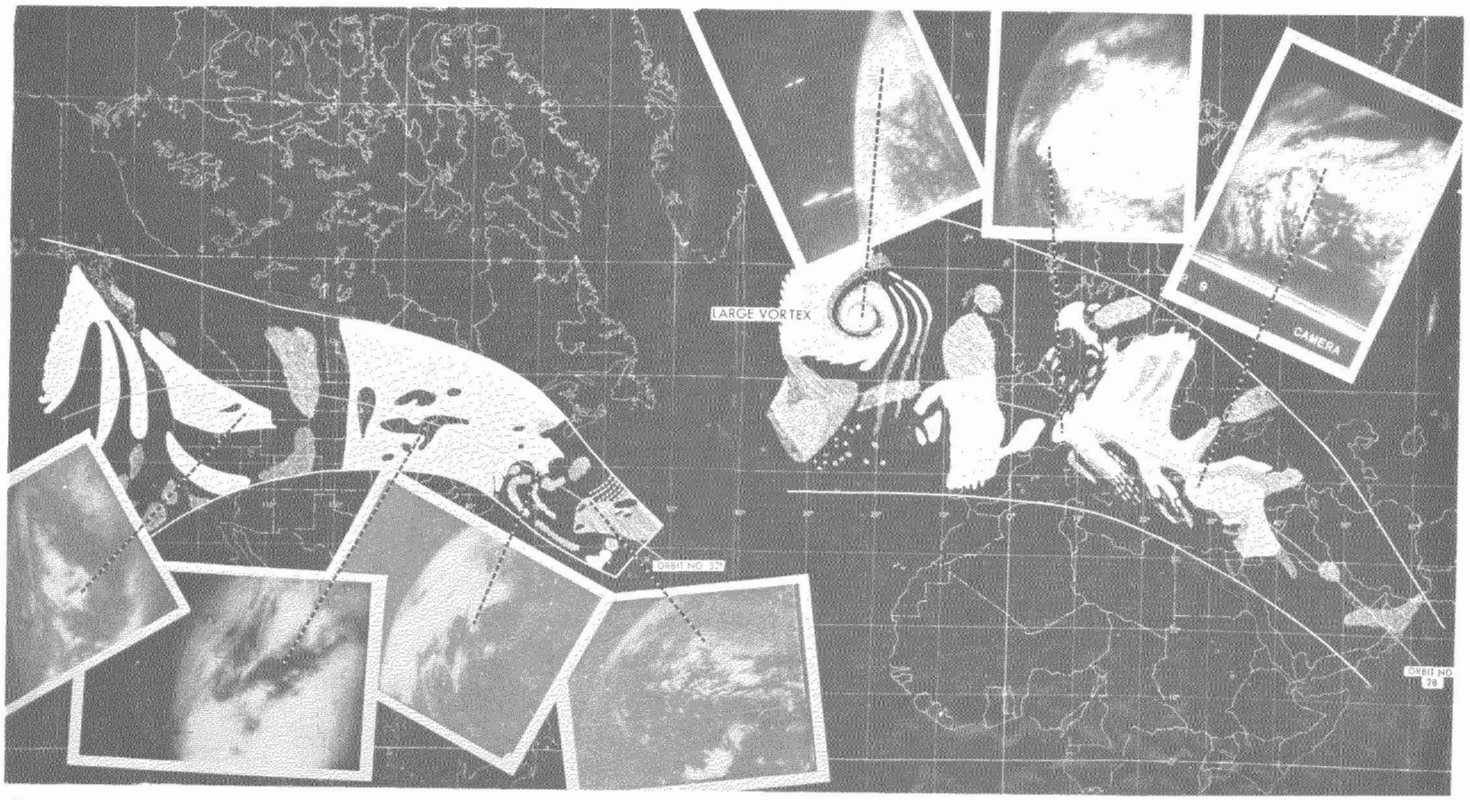


FIGURE 10.—A preliminary schematic representation of cloud patterns revealed by TIROS pictures over an area extending from the west coast of the United States into the Atlantic Ocean (orbit 32) and from the mid-Atlantic to the Near East (orbit 28), April 3, 1960. The solid white lines outline the area covered by pictures on these two orbits. Examples of pictures used in preparing the schematic cloud map are shown along the borders of the area.

getting under way. In the months ahead pictures are expected to reveal much new information about many atmospheric processes—from fair weather situations to incipient storminess to the growth of fully mature storms and their final dissipation.

ACKNOWLEDGMENTS

Thanks are due to L. T. Tourville of the Meteorological Satellite Section who helped with preparation of the photographs for publication; W. H. Hoecker, Jr., of the Office of Meteorological Research who performed the meticulous and laborious work in preparing figure 10 from scores of individual photographs; Marshall Kathan, Chief of the Drafting Section, who supervised and personally assisted in the speedy preparation of illustrations from which the figures were extracted; L. E. Johnson, E. R. Orr, J. H. Morrison, and A. Y. Gardner of the Printing Section who gave excellent service in reproduction of the photographs; James E. Caskey, Jr., the editor, who not only suggested publication of the paper but together with Mrs. Bernice Baddy of his staff assisted greatly in its preparation.

REFERENCES

1. S. Fritz, "On Observing the Atmosphere from Satellites—I. Cloud Observations," *Weatherwise*, vol. 12, No. 4, August 1959, pp. 139–144, 163–165.
2. W. G. Stroud, "Initial Results of the TIROS I Meteorological Satellite," *Journal of Geophysical Research*, vol. 65, No. 5, May 1960, pp. 1643–1644.

548229—60——2